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(54) 5V tolerant I/O circuit

(57) An integrated circuit has an I/O circuit that is connected to an I/O PAD. The I/O PAD may have greater voltage than the VDD associated with the integrated circuit so there is provided a switching circuit (51) that is connected between the VDD and the I/O PAD. An output buffer circuit is also provided that comprises n-channel

transistors (55) connected between the PAD and the ground. There is a cascode arrangement of p-channel transistors (53) connected between the I/O PAD and VDD.

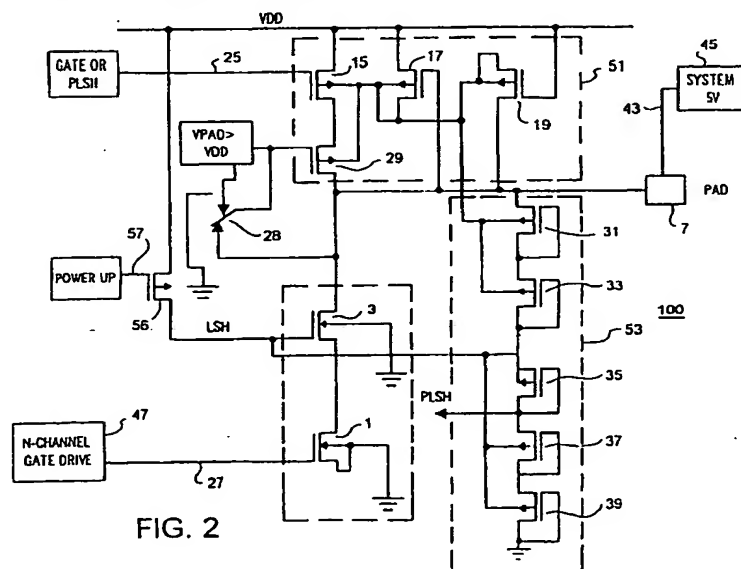


FIG. 2



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# EUROPEAN SEARCH REPORT

Application Number  
EP 98 10 2094

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP 0 323 643 A (TOKYO SHIBAURA ELECTRIC CO) 12 July 1989	1	H03K3/00 H03K19/003
A	* column 5, line 7 - column 9, line 13; figures 1,2 *	3	
X	--- "OVERVOLTAGE PROTECTION CIRCUIT" IBM TECHNICAL DISCLOSURE BULLETIN, vol. 30, no. 12, May 1988, page 96/97 XP002017155	1	
A	* the whole document *	3	
A	--- EP 0 704 973 A (SYMBIOS LOGIC INC) 3 April 1996 * the whole document *	1-10	
A	--- US 5 117 129 A (HOFFMAN JOSEPH A ET AL) 26 May 1992	1-10	<div>TECHNICAL FIELDS SEARCHED (Int.Cl.6)</div> <div>H03K</div>
A	--- US 5 570 043 A (CHURCHILL JONATHAN F) 29 October 1996 * column 6, line 66 - column 7, line 18; figures 3,4 *	1	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 6 November 1998	Examiner Feuer, F
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

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drive 47 provides a gate signal via conductor 27 to transistor 1. Additionally, transistor 3 gate is connected to VDD when VDD is powered up or to an intermediate voltage when the voltage on pin 7 is greater than VDD. Transistor 56 connects VDD to the gate of transistor 3 when VDD is not equal to zero voltage.

The potential divider 53 is a cascode arrangement of transistors 31, 33, 35, 37 and 39 that is connected between PAD 7 and around. The drains and gates of each transistor are connected together. The n-wells of transistors 31 and 33 are connected to the n-wells of the p-channel output buffer. Additionally, the drain of transistor 33 and the source of transistor 35 provides an intermediate voltage LSH to the gate of transistor 3 as well as the drive potential to the n-wells of transistor 35, 37 and 39. LSH controls the gate of transistor 3 when VDD is equal to zero and there is a voltage present on PAD 7 (power up). A second intermediate voltage is provided at the junction of the drain of transistor 35 and the source of transistor 37 denoted as PLSH. PLSH is used to control transistor 15 when the voltage on PAD 7 [VPAD] is greater than VDD.

The cascode of two p-channel transistors 29 and 15 between VPAD and VDD withstands the applied voltage differential VPAD minus VDD. In this cascode, the p-channel transistor 29 connected to VPAD is turned off when VPAD is greater than VDD by driving its gate to VPAD. This prevents current flow from VPAD to VDD. The gate of the second p-channel transistor 15 is connected between the p-channel transistor 29 and VDD is driven to an intermediate voltage such that the p-channel transistor 29 and the p-channel transistor 15 divide up the voltage VPAD minus VDD between them. The intermediate voltage is provided by a tap between transistors 35 and 37.

The PAD 7 is connected to a system 41 that contains, in the case of this embodiment, 5 volts. The system 41 is connected to PAD 7 via conductor 43.

Although the invention has been described with VDD at approximately 3.3 volts and a maximum voltage on the PAD is 5 volts, it is well known that the semiconductor industry is trying to establish standardized voltages. In fact, in the future, this may happen but regardless there will always be mixed signals on buses such as at 43 and this invention will work equally well where the voltage provided by the system 41 is 3.5 and VDD is at 2.5 voltage. This embodiment can still be used to protect the transistors and circuits with minor modification to the potential divider 53.

In Figure 3, to which reference should now be made, there is shown a block diagram of an input/output circuit 10 that includes an output buffer controller 61. The output buffer controller 61 drives a slew rate control logic 63 and a level shifting circuit 65. The output of the level shifting circuit 65 is fed back to the slew rate control logic 63 and also to a plurality of output buffers 67. The output buffer 67 is connected to the PAD 7.

The PAD 7 is both an input and output PAD. Con-

sequently, there is an ESD protection circuit 69 provided. The output of the ESD protection circuit is applied to a receiver 75 which transfers data via connection 77 to the remaining circuits contained within the integrated circuit in which the I/O circuit 10 is a portion of.

Figure 4 is the slew rate controller and it shows the generation of a PD signal which is connected to the output driver circuits of Figure 6.

Figure 5 is a schematic layout of a level shifting circuit 65 and illustrates the generation of the PLSH/LSH circuits as was discussed in connection with Figure 2. A second signal PLSH 2 is generated in the embodiment of Figure 5 which is used to drive the output drivers of Figure 6 and is denoted as PD and is applied to the output drivers via the slew rate control circuit of Figure 4.

The output drivers of Figure 6 is the output stage and is the circuits that are known in the art.

### Claims

#### 1. An I/O circuit comprising:

an I/O PAD connected to a first voltage;

an output buffer circuit having at least one first type transistor connected between the second voltage and the I/O PAD and at least one second type transistor connected between the I/O PAD and a third voltage; and

a cascode arrangement of a plurality of first type of transistors between the I/O PAD and the third voltage.

#### 2. The I/O circuit according to claim 1 further comprising:

a gate control circuit operatively connected to the output buffer circuit.

#### 3. The I/O circuit according to claim 1 wherein each transistor of the plurality of transistors include a source and a gate with the gate being connected to the source.

#### 4. The I/O circuit according to claim 3 wherein the plurality of transistor is a potentially divided.

#### 5. The I/O circuit according to claim 4 wherein the potential divider includes a first tap for providing a first gate control signal to the output buffer when the second voltage is equal to zero and the first voltage is not equal to zero.

#### 6. The I/O circuit according to claim 5 wherein the potential divider includes a second tap that is applied to the output buffer when the first voltage is greater than the second voltage.

7. The I/O circuit according to claim 4 wherein the potential divider includes a first tap that is applied to the output buffer when the first voltage is greater than the second voltage. 5
8. The I/O circuit according to claim 4 wherein the potential divider includes a first tap for providing a first gate control signal to the output buffer at a gate of the second type of transistor when the second voltage is equal to zero and the first voltage is not equal to zero. 10
9. The I/O circuit according to claim 8 wherein the potential divider includes a second tap that is applied to the output buffer at a gate of the first type of transistor when the first voltage is greater than the second voltage. 15
10. The I/O circuit according to claim 4 wherein the potential divider includes a first tap that is applied to the output buffer at a gate of the first type of transistor when the first voltage is greater than the second voltage. 20

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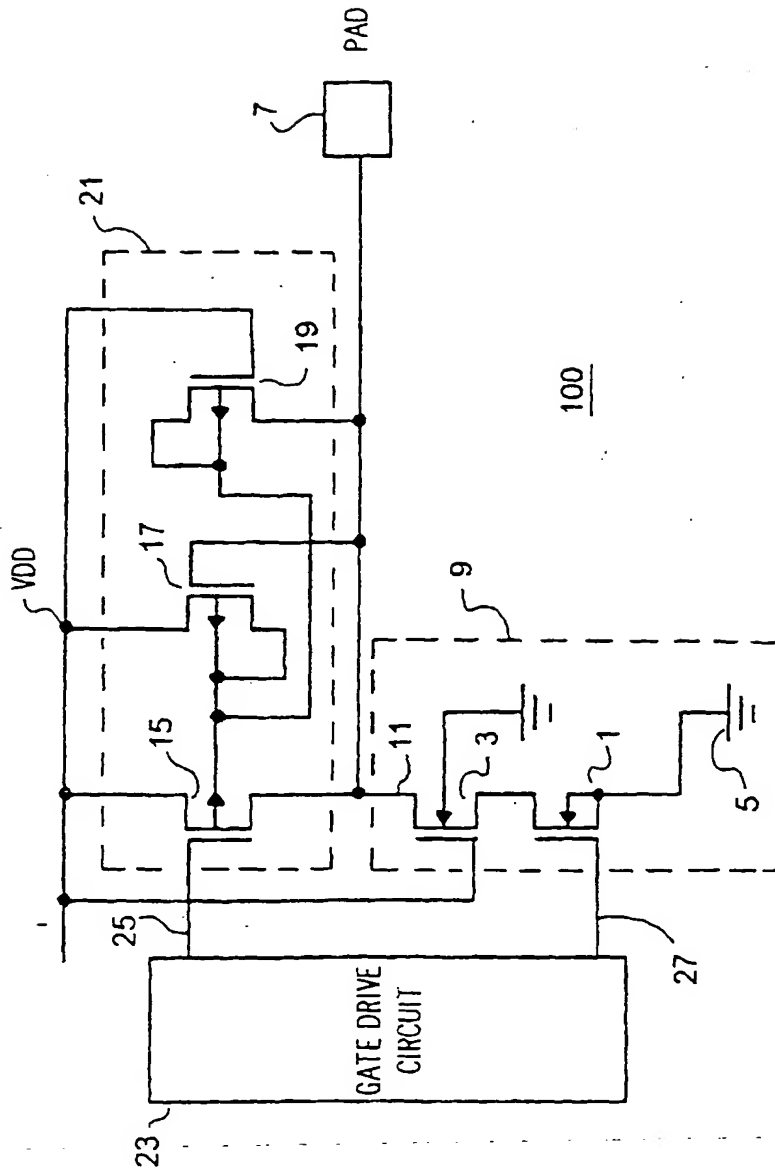


FIG. 1

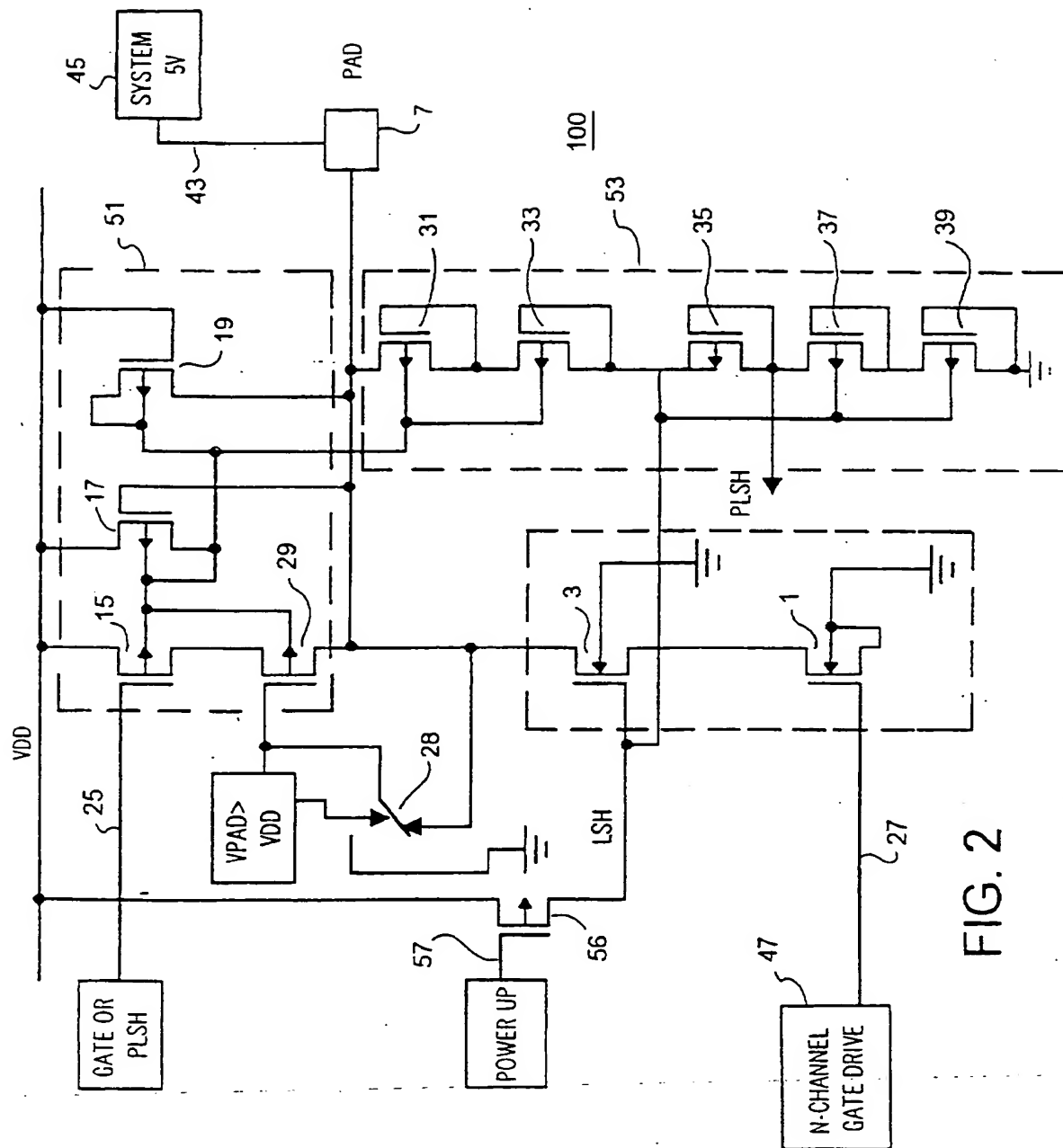


FIG. 2

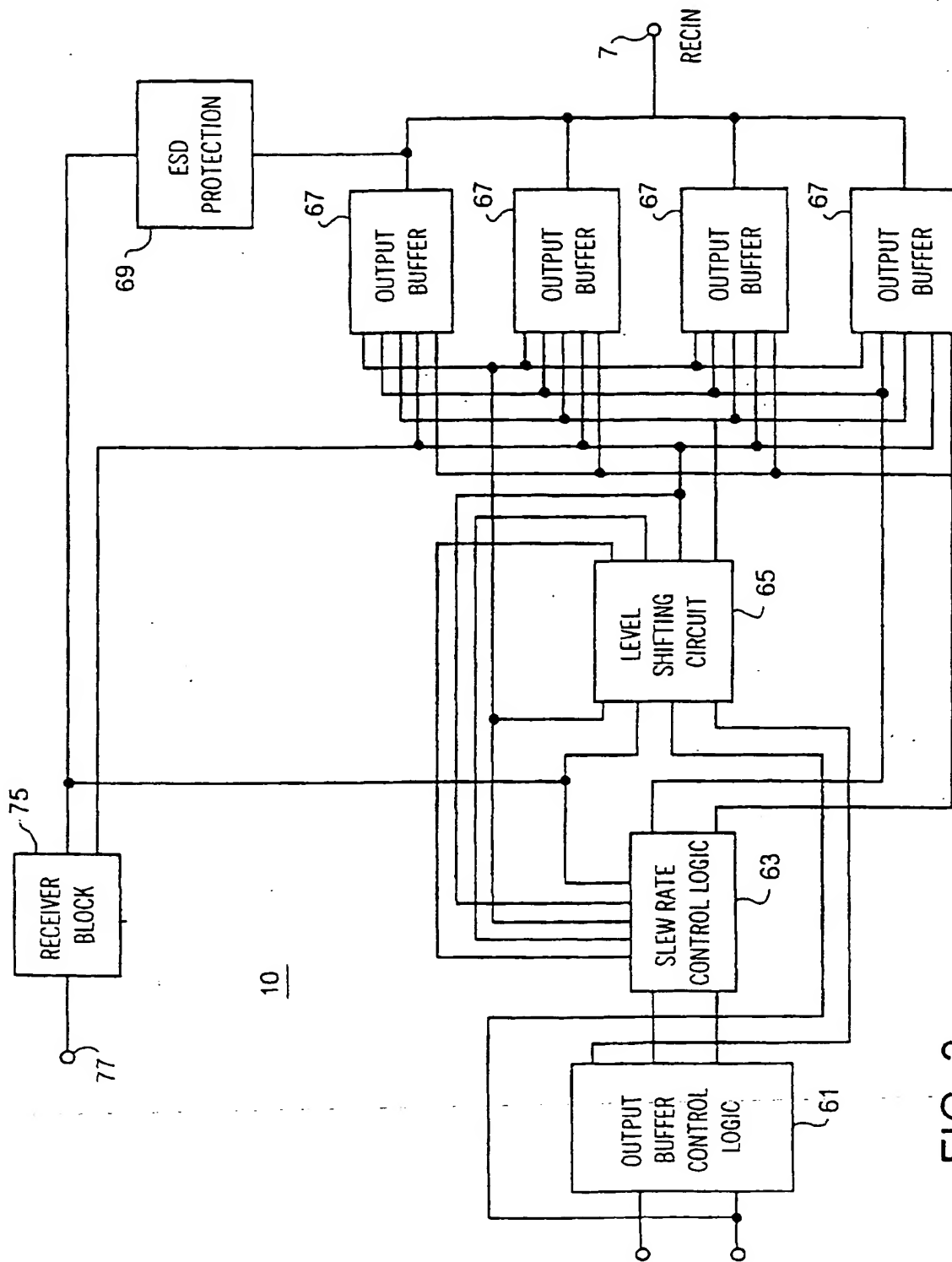


FIG. 3

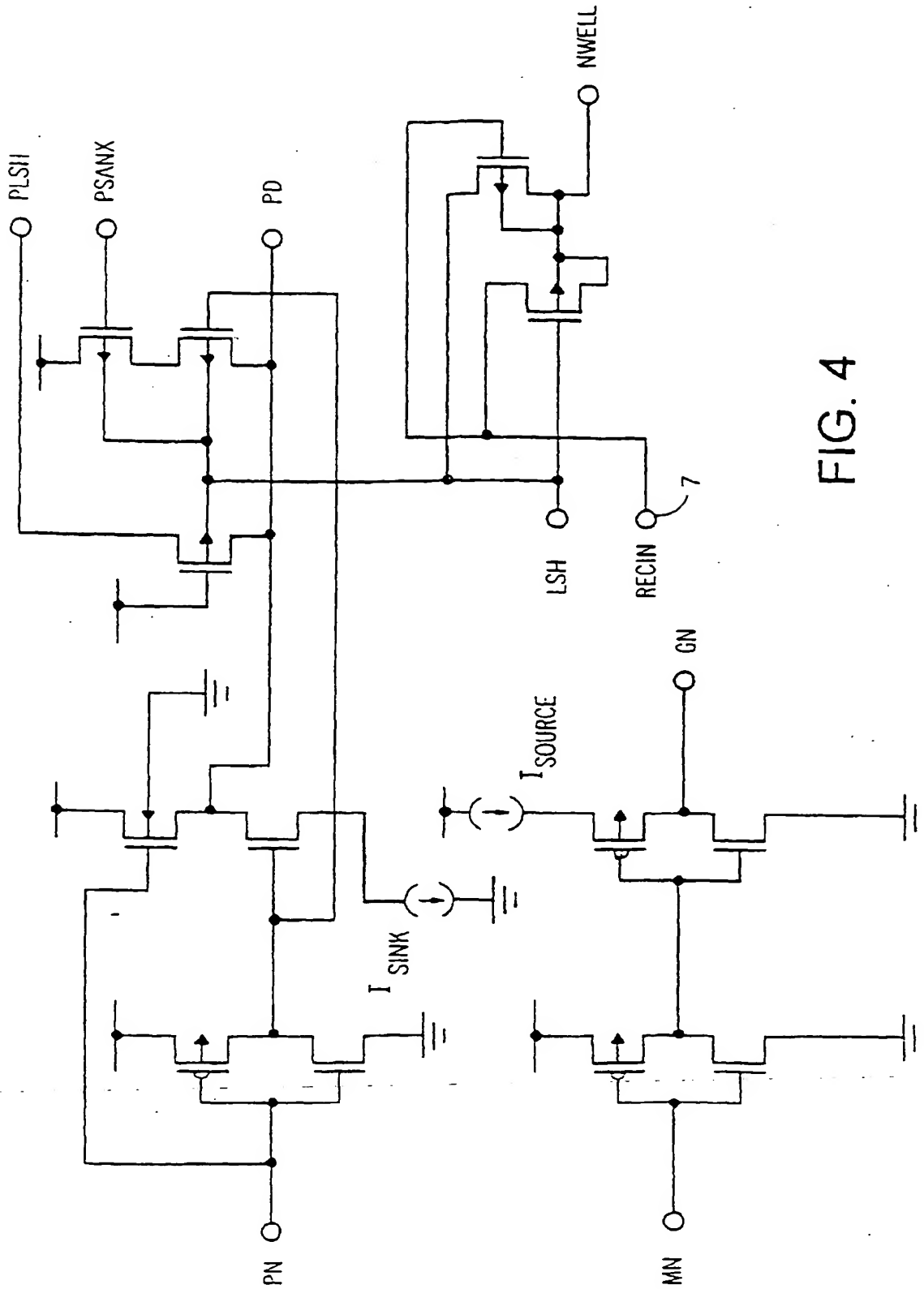


FIG. 4

## Description

### BACKGROUND OF INVENTION

This invention relates to input/output (I/O) circuit of an integrated circuit that is tolerant of 5 volts being connected to its I/O PAD. More particularly, this invention relates to I/O circuit for integrated circuits that are tolerant of 5 volts being connected to its I/O PAD even when there is no power applied to the integrated circuit.

The I/O circuit for integrated circuits are typically connected to a system's bus which may have a voltage level present even when the integrated circuit itself is not enabled or powered up. Under these conditions, it is important that the VDD of the integrated circuit should remain at ground level and not have a voltage potential on it by the presence of a 5 volt signal on the I/O PAD.

The challenge presented to a designer of I/O circuits is increased by the design rules associated with 0.35 micron processes or less. These transistors can only withstand a maximum of 4 volts across the gate oxide or 4 volts dropped from drain and to source.

The prior art method of designing I/O circuits to provide 5 volt tolerance are only effective when the integrated circuit's VDD supply is raised to approximately 3.3 volts. An example of the prior art output buffers is shown in Figure 1 to which reference should now be made.

The output buffer consists of two n-channel transistors. Transistor 1 and transistor 3 are connected in a cascode arrangement 9 between the output PAD 7 and the ground 5. Transistor 3 has its drain 11 connected to the PAD 5 and uses VDD as a gate voltages as illustrated by connection 13 ensuring that the voltage on the PAD 7 is divided between the transistors 1 and 3. A p-channel output buffer 21 includes transistors 15, 17 and 19. Transistors 17 and 19 switch the bulk of 15 to the higher of VDD or the PAD voltage. The gate of 15, when 15 is off, is switched under the control of the gate drive circuit 23 via conductor 25 to the higher voltage of VDD or the voltage on PAD 7.

In the embodiment of Figure 1, when VDD is zero such as when the integrated circuit to which the input/output circuit 10 is associated is not turned on and there is 5 volts on the PAD 7 then the voltage drop across transistors 15, 17 and 19 will exceeds 4 volts. This results in damage to each of the transistors. Similarly, the n-channel transistor 3 will have 5 volts from the drain 11 to the gate or conductor 13 damaging the gate oxide.

### SUMMARY OF THE INVENTION

An integrated circuit has an I/O circuit that is connected to an I/O PAD. The I/O PAD may have greater voltage than the VDD associated with the integrated circuit so there is provided a switching circuit that is connected between the VDD and the I/O PAD. An output

buffer circuit is also provided that comprises n-channel transistors connected between the PAD and the ground. There is a cascode arrangement of p-channel transistors connected between the I/O PAD and VDD.

The cascode arrangement performs the function of a potential divider for producing intermediate voltages. The intermediate voltages are used to control the gates above the cascoded n-channel and p-channel transistors. The use of the intermediate voltages protects all transistors from breakdown.

### BRIEF DESCRIPTION OF THE FIGURES

Figure 1 is a simplified schematic diagram of a prior art 5 volt tolerant I/O circuit;

Figure 2 is a simplified schematic diagram of an I/O circuit according to the invention;

Figure 3 is a block diagram of an I/O circuit according to the invention;

Figure 4 is a schematic diagram of the slew rate control circuit of Figure 3;

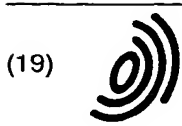
Figure 5 is a schematic diagram of the level shift circuit of the embodiment of Figure 3; and,

Figure 6 is a schematic diagram of the output drivers of the embodiment of Figure 3.

### DETAILED DESCRIPTION OF THE EMBODIMENT

Figure 2, to which reference should now be made, there is shown a simplified schematic diagram of an output section 100 of an I/O circuit according to the invention. The output section includes a p-channel output buffer 51; an n-channel output buffer 55; and a potential divider circuit 53. The p-channel output buffer 51 has a transistor 19 with its gate connected to VDD and its source connected to the PAD 7. The drain of transistor 19 is connected to its n-well and also is connected to the drain and n-well of transistor 17 as well as the n-well of transistors 15 and 29. Transistor 17 source is connected to VDD with the gate connected to the PAD 7. Transistor 15 source is connected to VDD, the gate is connected to a switch that is used when the voltage on PAD 7 is less than VDD. Transistor 29 is a transistor that is enabled and switched on when the voltage on the PAD 7 is less than VDD. Gate of transistor 29 is connected to the PAD voltage by the action of switch 28 to switch off transistor 29, when VPAD exceeds VDD.

The n-channel output buffer 55 includes transistors 1 and 3 that are arranged in cascode arrangement. The drain of transistor 3 is connected to the PAD 7 where the source is connected the drain of transistor 1. The source of transistor 1 is connected to ground as it the p-well of both transistors 1 and 3. The n-channel gate



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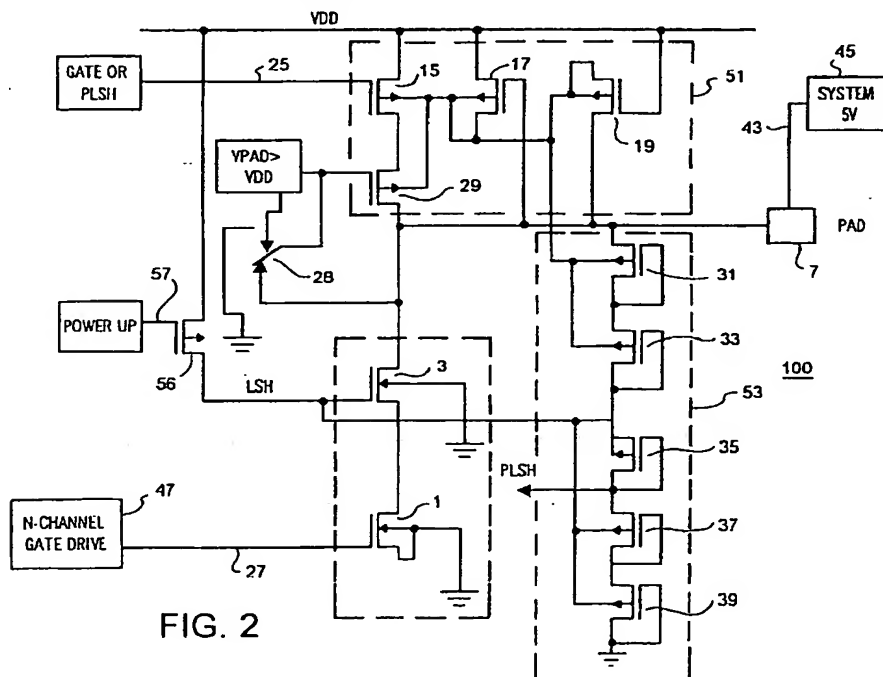


FIG. 2

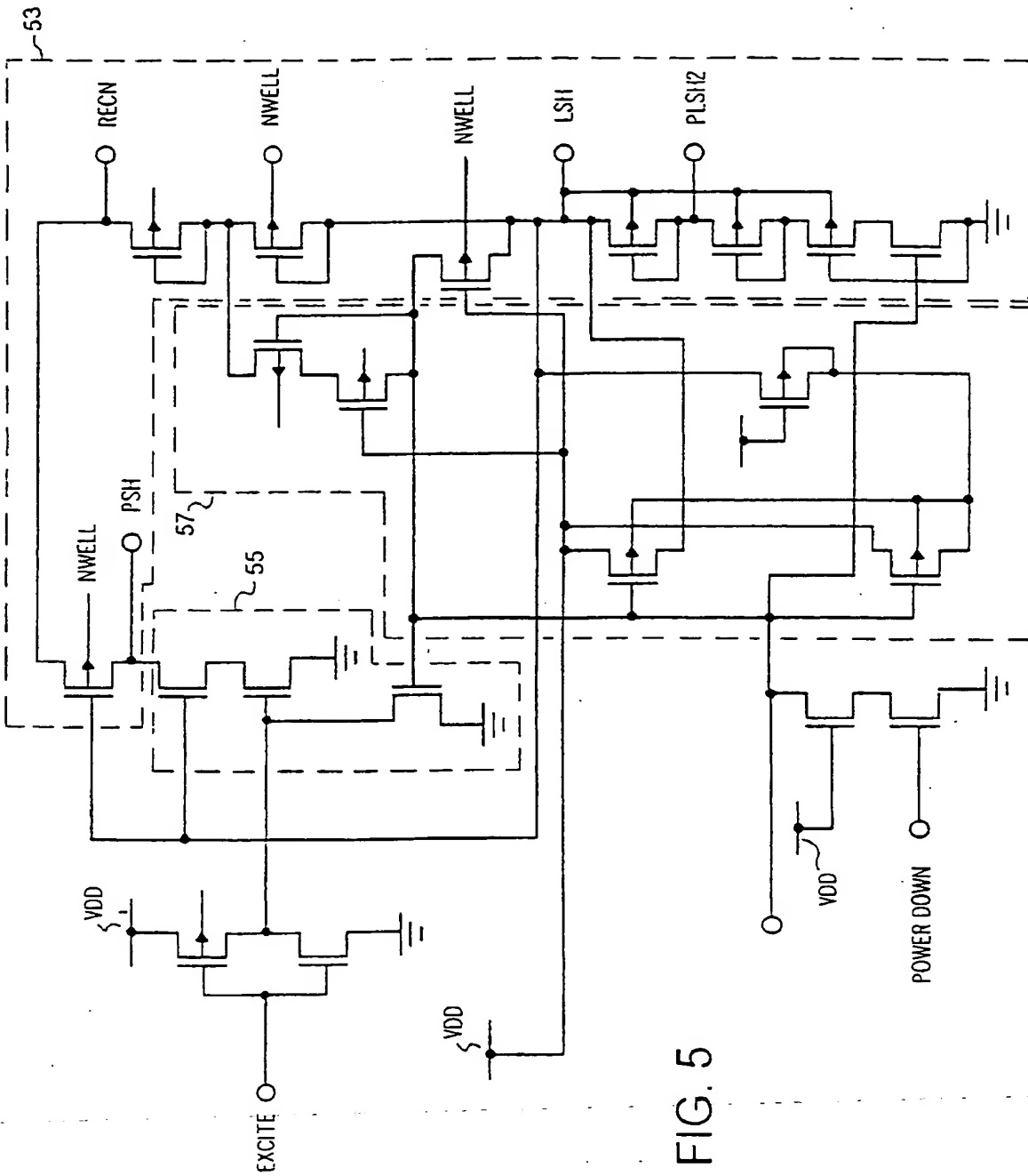


FIG. 5

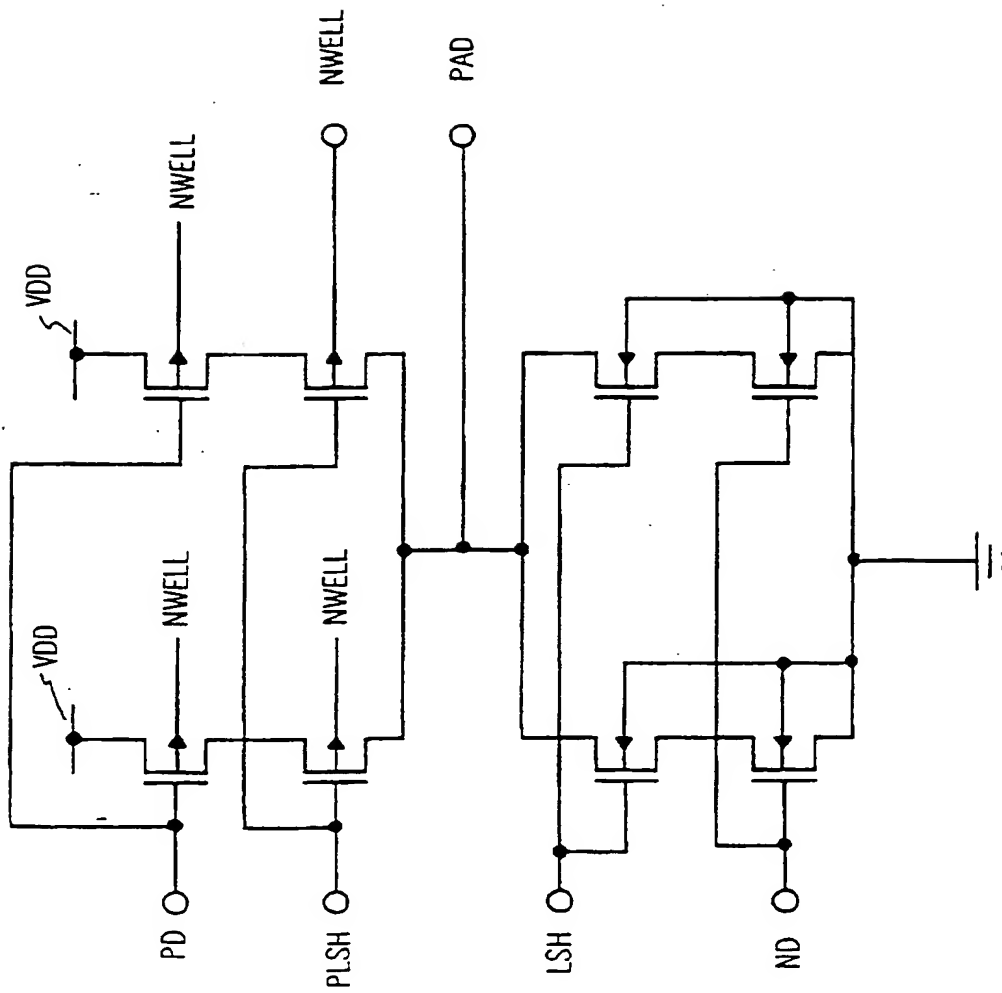


FIG. 6